CEER Report on Power Losses

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INFORMATION PAGE

Abstract

This document (C17-EQS-80-03) is a Report on Power Losses from the Council of European Energy Regulators (CEER).

This report provides an overview of power losses (transmission and distribution) on electrical grids – the levels of losses, how they are defined, calculated and valued across 27 European countries. It is packed with key quality data such as the amount of technical and non-technical losses, losses in transmission and distribution systems, and procurement of losses. It includes case studies on the regulatory treatment of losses (e.g. the procurement of energy to cover power losses and compensations, incentives to network operators). The impact of smart meters and distributed generation on network losses is also addressed. Reducing power losses contributes to greater energy efficiency and security of supply and is an important goal, not least because the costs of power losses are often passed on to consumers.

This report contains a set of recommendations for good practices that could be adopted so as to better benchmark and reduce technical and non-technical losses.

CEER's findings and recommendations are based on the results of questionnaires sent to National Regulatory Authorities (NRAs) and stakeholders.

Target Audience

European Commission, CEER Members, National Regulatory Authorities (NRAs), Transmission System Operators (TSOs), Distribution System Operators (DSOs), Independent System Operators (ISOs), energy suppliers, traders, electricity customers, electricity industry, consumer representative groups, network operators, Member Countries, academics and other interested parties.

Keywords

Power Losses; Transmission; Distribution; Energy Efficiency Directive; Transmission Grid; Distribution Grid; Electrical Grid; Cross-Sectoral; Networks; Energy Efficiency; Market Monitoring; National Regulatory Authorities (NRAs); Transmission System Operators (TSOs); Distribution System Operators (DSOs); Independent System Operator (ISO); Independent Transmission Operator (ITO); Distributed Generation; Smart Meters

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Related Documents

CEER documents

- "Treatment of Losses by Network Operators - ERGEG Position Paper for public consultation", European Regulators' Group for Electricity and Gas (ERGEG), July 2008. http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/ELECTRICITY/Treatment%20of%20Losses/CD/E08-ENM-04-03_Treatment-of-Losses_PC_2008-07-15.pdf

- "Treatment of Electricity Losses by Network Operators - ERGEG Position Paper / Conclusions Paper" European Regulators' Group for Electricity and Gas (ERGEG), February 2009. https://www.ceer.eu/documents/104400/-/-/6f455336-d8c8-aa6f-36d3-fe5264caf57d

- 6th CEER Benchmarking Report on the Quality of Electricity and Gas Supply, August 2016. https://www.ceer.eu/documents/104400/-/-/d064733a-9614-e320-a068-2086ed27be7f

External documents are listed in Annex 4

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1 Background

There have been some publications on power losses on a European level in the past. In 2008, the European Regulators' Group for Electricity and Gas (ERGEG, the predecessor of the Agency for the Cooperation of Energy Regulators (ACER)) conducted a consultation on the treatment of losses by network operators for fourteen European Union (EU) countries, marking the first analysis of this topic by European energy regulators.[1] Subsequently, ERGEG issued a position paper on the treatment of losses by network operators.[2] In 2014 the European Commission published a Communication on energy efficiency, noting the need to reduce the volume of network losses to achieve the 2030 objective.[3]

In 2015, the European Commission published a report in support of the implementation of Article 15 of the Energy Efficiency Directive (2012/27/EU) which gives a comprehensive overview of the different types of losses, factors that affect the value and the origin of losses, and regulatory treatment of losses across EU Member States.[4]

Several papers dealing with power losses have also been published by the International Conference on Electricity Distribution (CIRED). These papers addressed multiple topics, such as an assessment of technical losses in distribution systems with reduced measurement capabilities, the impact of photovoltaics on distribution network losses, an analysis of losses in a distribution grid with high penetration of distributed generation and an assessment of investment efforts in high and medium voltage networks to reduce losses and general opportunities for reduction of losses in distribution systems.

With the aim of facilitating an exchange of information between the stakeholders and national regulatory authorities (NRAs), CEER organised a workshop on Power Losses on 6 October 2016. The workshop was supported by presentations from representatives of system operators, regulatory authorities and the CEER's dedicated task force on electricity quality of supply (EQS). The workshop was attended in-person and via web-streaming by individuals from Europe, the Middle East, Africa as well as Latin America.

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[1] "Treatment of Losses by Network Operators - Ergeg Position Paper for public consultation", European Regulators' Group for Electricity and Gas (ERGEG), July 2008. http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/ELECTRICITY/Treatment%20of%20Losses/CD/E08-ENM-04-03_Treatment-of-Losses_PC_2008-07-15.pdf

[2] "Treatment of Electricity Losses by Network Operators - ERGEG Position Paper / Conclusions Paper" European Regulators' Group for Electricity and Gas (ERGEG), February 2009,

https://www.ceer.eu/documents/104400/-/-/6f455336-d8c8-aa6f-36d3-fe5264caf57d

[3] "Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy", The European Commission, July 2014, http://eur-lex.europa.eu/resource.html?uri=cellar:f0db7509-13e5-11e4-933d-01aa75ed71a1.0003.03/DOC_1&format=PDF

[4] "Identifying energy efficiency improvements and saving potential in energy networks, including analysis of the value of demand response", DG Energy, European Commission, 18 December 2015, https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

2 Executive Summary

Power losses are an inevitable consequence of transporting electricity across the power grid. The technical component of losses, i.e., the energy converted to heat and power, is the most prominent one, but non-technical components, in other words, the energy delivered but not metered or billed, are very influential in certain CEER Member Countries (henceforth simply Member Countries unless otherwise noted) and often depend on socio-economic aspects.

Reducing losses, or at least maintaining them at a low level, plays an important role financially, environmentally and technically. Reducing power losses helps with Europe's energy efficiency and security of supply objectives. Reducing power losses is also an important part of CEER's mission of putting consumers first, as the costs of power losses are currently passed on to consumers. CEER advocates implementing incentives to reduce power losses.

Objective and scope
As a result of a 2016 CEER questionnaire, input from NRAs of 27 CEER Member Countries was received, as well as additional input from 21 stakeholders. Analysis of responses revealed that there are significant differences not only in the levels of losses but in the way losses are approached, defined, measured and treated in responding countries.

The objective of this report is to make an inventory of the treatment of losses in Europe (definition, calculation and value of losses), present the level of losses, highlight how smart meters and increasing distributed generation are likely to affect network losses, and provide a set of findings and recommendations. It includes case studies on the regulatory treatment of losses (e.g. the procurement of energy to cover losses and compensation issues).

Lack of harmonised definitions
While most responding countries define losses as the difference between injected and withdrawn energy, there are a few exceptions to this general rule. The lack of harmonised definitions and rules hinders a straightforward benchmarking of power losses across Europe. This means that there are differences in terms of which components of losses are considered (especially when dealing with non-technical losses), in the measuring tolerance of meters, whether imported and exported energy is included in injections and withdrawals and whether the energy needed for grid operation (own consumption) constitutes a share of reported power losses. While all responding countries include the technical component in their reported losses, there are many practices when it comes to non-technical losses and no common position whether and which components of non-technical losses should be included. This means that the results presented in this report should be approached with caution and that potentially differing approaches to losses should be kept in mind when making direct comparisons between the countries.

Transmission and distribution losses
Another division of losses is in terms of those in transmission and those in distribution, considering their different voltage levels. Since technical losses are proportional to the current flowing through lines, lower current results in lower technical losses percentagewise. This is the case for transmission systems which generally have higher voltage but lower current.

<u>Calculation of losses</u>
Losses can either be determined by direct metering or estimation. Metering is mostly used in transmission while estimation of losses is often used in distribution. Comparing losses in absolute terms (rather than as a percentage) would misrepresent the situation in larger countries, in the sense that larger countries will show larger absolute losses than smaller ones simply because their systems are larger. For this reason, the losses presented in this report were calculated as a percentage of total energy injected in a system. This is the case not only for overall losses in a Member State, but also for separate losses in transmission and distribution. This method might have resulted in values that differ from those typically calculated by the system operators but was unavoidable, due to anticipated difficulties of obtaining separate and plausible values of energy injected in transmission and distribution grids.

<u>Levels of power losses in Europe</u>
Losses in transmission seem stable in the analysed timeframe (2010 to 2015) but can vary from year to year, due to a variety of factors which may be specific to each network system. Overall, in **2015** we note a range of between **0.89% and 2.77% in power losses at transmission level** as a proportion of total energy injected across the surveyed countries. In comparison, the **total losses (transmission and distribution) for the same year range between 2.24% and 10.44% across Europe**. Since the definitions of voltage levels are not standardised across Europe, countries where transmission system operators deal with voltage levels lower than those typically used for transmission could have higher transmission losses as a consequence. Losses in distribution have the highest potential for reduction as non-technical losses play an important role in this case. Generally, the majority of power losses occur close to the customer, on low voltage networks followed by medium voltage grids.

<u>Regulatory treatment of losses</u>
Procurement of losses, defined as the procedure implemented in each country to handle the coverage of power losses, is either the responsibility of network operators (in most countries) or the suppliers (in Great Britain, Ireland, Portugal, Spain and partly in Belgium). Regarding the regulatory treatment of losses, the aim of incentives is to enable NRAs to ensure that Transmission System Operators (TSOs) and Distribution System Operators (DSOs) implement all the economically efficient operational and investment decisions aimed at limiting/reducing the volume and the costs of the energy necessary to cover power losses. Responses to the CEER questionnaire show that incentives in almost all Member Countries apply only to DSOs. Countries that employ incentives to regulate power losses either consider the cost of losses as part of the general revenue cap (where losses are treated the same way as system operators' other costs), or allow a predetermined capped rate of losses to be included in tariffs, or allow their system operators to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value.

<u>Distributed generation and losses</u>
The effect of distributed generation on losses is an increasingly relevant issue which might lead to two contrary effects regarding network losses. If decentralised energy sources are located near the point of consumption and if generation coincides with consumption, distributed generation contributes to reducing power losses. If distributed generation is located far from consumption centres or if generation does not coincide with consumption, losses might increase. The main reason for this is the increased distance of power flows.

Technical losses are affected to a large extent by the changing network architecture which has to take into account a significant increase in distributed generation, while non-technical losses might be strongly influenced by the increased usage of smart meters, among other things. A higher penetration rate of smart meters would result in a reduction of electricity theft and more accurate recording of electricity consumption.

Who pays for losses?

In many cases across Europe the costs for losses are passed on to consumers, giving system operators no incentive to reduce network losses. Proper measures should be introduced to incentivise system operators to reduce losses in their grids or at least maintain them at low levels if they are already efficient. Moreover, different regulatory approaches could be implemented for technical and non-technical losses to facilitate the most efficient regulatory schemes.

Losses are one of the key contributors to operational expenditures in power networks. CEER recommends that system operators aim to find the right balance between the managing the costs of losses and costs of investing in more efficient technologies.

CEER makes the following recommendations for reducing electricity network losses:

Overall:

1) Harmonise definitions for improved benchmarking
2) Make more data available, such as the availability of energy injected into distribution grids, which would permit the calculation of distribution system losses as a percentage of energy injected into distribution grids
3) Incentivise system operators to reduce losses instead of passing losses on to consumers
4) Employ a life cycle costing approach that includes losses when making investment decisions

Technical losses:

1) Increase voltage levels
2) Apply less transformational steps to deliver electricity to consumers
3) Utilise new and improved equipment
4) Employ distributed generation in a more efficient manner, including combining it with local storage
5) Optimise network flows – reduce peaking
6) In general, pursue network architecture and management that promote the highest efficiency

Non-Technical losses:

1) All countries should collect data on these types of losses
2) Focus on more accurate recording of electricity consumptions through improved metering and the use of smart meters
3) Reduce theft and other hidden losses

3 Introduction

Power losses are an inherent part of electrical grids. They are a consequence of transmission and distribution of electrical energy and will always be part of any traditional electrical system. In addition, aspects such as fraud in distribution and inaccuracies of conventional electricity meters are also contributing factors.[5] Losses do constitute an important amount of energy flows in transmission and distribution networks. With energy efficiency concerns, reduction of losses takes an increasingly important role, both for reasons of financial sustainability and for improving system quality and reliability. There is a major environmental benefit in reducing power losses. There can also be a significant economic benefit if power losses are reduced cost effectively.

Article 15 of Directive 2012/27/EU on energy efficiency, states that the "[EU] Member States shall ensure that network operators are incentivised to improve efficiency in infrastructure design and operation” and that the "[EU] Member States shall ensure that national energy regulatory authorities pay due regard to energy efficiency in carrying out the regulatory tasks specified in Directives 2009/72/EC and 2009/73/EC regarding their decisions on the operation of the gas and electricity infrastructure".[6] Reducing the volume of power losses represents one way to fulfil this energy efficiency objective.

Improving energy efficiency implies the minimisation or at least a significant reduction of losses in electricity transmission and distribution networks. This concerns gas as well, however losses in gas networks, often referred to as “shrinkage”, are beyond the scope of this report.

An analysis of the level of losses in electricity networks for a number of Member Countries was conducted for this report, revealing a huge dispersion of the level of losses. These results indicate that the potential for energy efficiency improvement differs significantly from country to country and mostly depend on local conditions.

This report is based on responses to the 2016 CEER questionnaires on power losses sent to National Regulatory Authorities (NRAs) and stakeholders. The objective of the report is to make an inventory of the treatment of losses in Europe (definition, calculation, value and regulatory treatment of losses), address the impact of smart meters and distributed generation on losses and to present CEER’s main findings and recommendations. A more-detailed analysis of practices in certain countries are included in the form of case studies.

5 “Maximising Benefits to Customers from Distribution Losses Management - an ESBN Perspective”, K. Niall und A. Walsh, June 2011, page 1, https://www.ceer.eu/documents/104400/-/-/22b711c1-ef33-e914-e3e1-9614385acb90

6 “Directive 2012/27/EU/ Of the European Parliament and the Council”, Official Journal of the European Union, October 2012, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF

4 Inventory

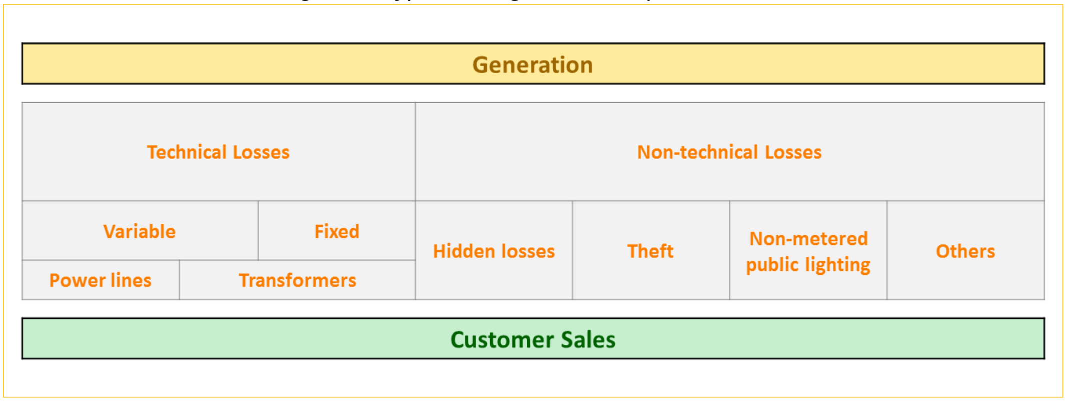
4.1 Definition of losses

In general, the understanding of losses – regardless of their origin – is that they are a representation of the difference between all the energy that is injected into a system (which includes not only generation but in some cases also imported energy) and the billed energy consumed (energy going out of a system would also include exports in some cases).[7]

Energy losses in electricity grids can result from various mechanisms which affect the different network components.[8] Figure 1 presents an overview of a commonly used categorisation of losses. This classification is not intended to be exhaustive, but is a representation of what is usually discussed and of that which is objective of the CEER questionnaire and of this report.

In order to analyse the impacts of these components and the potential of energy efficiency measures, it is useful to understand how losses are categorised.

Figure 1: Typical categorisation of power losses



As shown in Figure 1, the most common way to categorise losses is into those of technical and those of non-technical nature.

- Technical losses refer to energy converted to heat in power lines and transformers,[9] resulting from the laws of physics. Since technical losses are an outcome of technical features, they can be estimated quite accurately and are in some ways determined by the properties of the grid and its components.
- Non-technical losses, on the other hand, refer to energy delivered and consumed, but for some reason not recorded by a meter.

[7] “Treatment of Losses by Network Operators - Ergeg Position Paper for public consultation”, European Regulators’ Group for Electricity and Gas (ERGEG), July 2008, page 5 Ref. 4, http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/ELECTRICITY/Treatment%20of%20Losses/CD/E08-ENM-04-03_Treatment-of-Losses_PC_2008-07-15.pdf

[8] “Identifying energy efficiency improvements and saving potential in energy networks, including analysis of the value of demand response”, DG Energy, European Commission, 18 December 2015, https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

[9] “Identifying energy efficiency improvements and saving potential in energy networks, including analysis of the value of demand response”, DG Energy, European Commission, December 2015, page 22, https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

There are more ways to categorise technical losses. One way is to examine whether they are fixed or variable.

- Fixed losses refer to energy needed for the energisation of transformers or conductors. They depend mainly on the number of energised components. Thus, the potential for a reduction of fixed losses will focus mainly on a reduction of the number of energised components or on how to increase their efficiency.[10] Another source of fixed losses is corona losses, which occur in high voltage lines. They vary with voltage level and physical wire diameter and with weather conditions such as rain and fog and generally contribute only a very small percentage to overall system losses.[11]
- Variable losses occur due to the heating effect of energy passing through conductors in lines and cables and also in the copper in transformers.[12] Variable losses vary in proportion to the square of the current and in proportion to the conductor resistance. Thus, any efforts in reducing variable losses will aim to reduce the system power flows or to reduce the resistance of the transport paths.

Since transformers and power lines are the primary components of infrastructure in electricity networks, they are the main source of technical losses.

On the other hand, non-technical losses comprise electricity which is delivered mostly for consumption but which is not billed. They are mainly caused by in-house consumption (also known as “hidden” losses); illegal consumption of electricity (energy theft); non-metered supply (such as public lighting); as well as errors in metering, billing and data processing. Additionally, errors may result from the time-lag between meter readings and statistical calculations. The following types of non-technical losses are considered in this report:

1. Hidden losses are typically associated with in-house consumption, but also with electricity consumed in order to cool transformers and operate the control system (sometimes referred to as own-consumption).
2. Non-metered supplies, which include public lighting, telephone booths, traffic lights etc. For practical reasons, consumption of this type of electrical installations is usually calculated by means of equipment inventories, estimated usage or known hours of operation, which in some cases might be rather inaccurate.
3. Theft consists of tampering with meters and performing illegal connections. It is difficult to check the exact extent of this type of losses as, by its very nature, a large proportion of it is likely to go undetected.
4. Finally, differences in metering, billing and data processing usually account for the remainder of non-technical losses.

A further distinction made is between losses in transmission and distribution grids. Since variable losses directly depend on the current, a higher voltage level with a lower current (corresponding to higher conductor diameter and lower resistance) results in a reduction of energy losses. For this reason, electricity transmission runs at high and extra high voltage levels.

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[10] “Identifying energy efficiency improvements and saving potential in energy networks, including analysis of the value of demand response”, DG Energy, European Commission, December 2015, page 23, https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

[11] “Incentives to improve energy efficiency in EU Grids”, Ecofys, April 2013, page 2, http://www.ecofys.com/files/files/ecofys-2013-incentives-to-improve-energy-efficiency-in-eu-grids.pdf

[12] “Identifying energy efficiency improvements and saving potential in energy networks, including analysis of the value of demand response”, DG Energy, European Commission, December 2015, page 23, https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

As a consequence of the wide range of sources for power losses, current regulatory definitions of this term vary significantly from country to country. For benchmarking purposes, this circumstance hinders the analysis of percentages of losses across countries (see Section 4.2.2).

In general, almost all reporting countries have the conventional understanding that losses are defined as the difference between energy injected in the grid and energy withdrawn from the grid during the same time interval. Some variations do exist, however. Several NRAs indicated that there is no legal definition of power losses in their country, since they are determined purely technically. It is important to keep in mind that the energy needed for grid operation (own consumption) can either be included in losses or considered separately, and that practices in this regard differ across Europe.

With a few exceptions (Estonia, Germany, Lithuania, and Norway) where only technical losses are considered, all responding countries include non-technical losses in their focus of regulation. However, it remains unclear how non-technical losses are typically regulated or if they are covered by tariffs in any way.

Do power losses refer only to technical losses or do they include non-technical losses too?			
No. of responses	Technical	No. of responses	Technical & Non-technical
(4)	DE, EE, LT, NO	(21)	AT, BE, CY, CZ, DK, EL, ES, FI, FR, GB, HR, HU, IE, IT, LV, NL, PL, PT, RO, SE, SI

Table 1: Monitoring of technical and non-technical power losses

When considering non-technical losses, it becomes clear that there are huge differences in components that are included in the calculated values of power losses. Only in a few countries are all four types of non-technical losses mentioned above included in overall losses. The majority of the reporting countries use some of the four components of non-technical losses but not all of them, which reveals that a comparison of losses might not be straightforward.

Which of the following types of losses are included in the calculation of losses in your country and on what network level?				
Type of Losses	No. of responses	Transmission	No. of responses	Distribution
Technical Losses[13]	(26)	AT, BE, CY, CZ, DE, DK, EE, EL, ES, FI, FR, GB, HR, HU, IE, IS, IT, LT, LV, NL, NO, PL, PT, RO, SE, SI	(26)	AT, BE, CY, CZ, DE, EE, EL, ES, FI, FR, GB, HR, HU, IE, IS, IT, LT, LV, MT, NL, NO, PL, PT, RO, SE, SI
Non-technical Losses – Hidden Losses	(8)	AT, DK, FI, IE, NL, PL, RO, SE	(15)	AT, BE, CY, ES, FI, HR, HU, IE, LV, MT, NL, PL, RO, SE, SI
Non-technical Losses – non-metered consumption	(9)	DK, GB, IE, LV, NL, PL, RO, SE, SI	(14)	BE, CY, CZ, ES, GB, HU, IE, LV, MT, NL, PL, RO, SE, SI

[13] The analysis of this (sub)question covers 26 countries in both transmission and distribution, rather than the total of 27 that were analysed in this report. Malta was left out of transmission because it does not have a transmission grid and Denmark did not provide an answer for distribution.

Which of the following types of losses are included in the calculation of losses in your country and on what network level?				
Type of Losses	No. of responses	Transmission	No. of responses	Distribution
Non-technical Losses – Theft	(13)	AT, CZ, DK, EL, FI, GB, IE, LV, NL, PL, PT, SE, SI	(22)	AT, BE, CY, CZ, EL, ES, FI, FR, GB, HR, HU, IE, IT, LV, MT, NL, NO, PL, PT, RO, SE, SI
Non-technical Losses – Others[14]	(16)	AT, CY, CZ, EE, ES, FI, FR, GB IE, LV, NL, PL, PT, RO, SE, SI	(23)	AT, BE, CY, CZ, EE, EL, ES, FI, FR, GB, HR, HU, IE, IT, LT, LV, MT, NL, PL, PT, RO, SE, SI

Table 2: Types of losses included in calculation

Following the CEER Workshop on power losses (October 2016), CEER disseminated a questionnaire for stakeholders as well, so that they were given the opportunity to communicate their views regarding the treatment of losses. The questions were similar to those in the questionnaire for NRAs, but focused more on the stakeholders' opinions of what might be the appropriate treatment of losses.

In total, CEER received answers from 21 stakeholders from across Europe (listed below in Table 3). Not all respondents provided answers to all questions or sub-questions; therefore, the number of responses on a particular question is sometimes lower than 21.

Stakeholder	Country
European Copper Institute	EU
Enedis	France
Enel	EU
EDP Distribuição - Energia, S.A.	Portugal
ESB Networks	Ireland
Finnish Energy	Finland
RTE	France
Iberdrola Distribución Eléctrica S.A.U.	Spain
Netze BW	Germany
TINETZ-Tiroler Netze GmbH	Austria
EDF SA	France
BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. (German Association of Energy and Water Industries)	Germany
Salzburg Netz GmbH	Austria
Netz Oberösterreich GmbH	Austria
Gas Natural Fenosa	Spain
Viesgo	Spain
Union Fenosa Distribution	Spain
Energy Norway	Norway
Energy Networks Association	United Kingdom
Hellenic Distribution Network Operator	Greece
KNG-Kärnten Netz GmbH	Austria

[14] Such as metering errors, differences in metering, billing, and data processing.

Table 3: Stakeholders that responded to the questionnaire

The stakeholders' views regarding a definition of losses were identical to that of the NRAs. Most stakeholders stated that losses should be defined as the absolute difference between the volume of energy entering the system (metered or estimated at the point of entry) and the customer-related volume of units exiting the system (metered or estimated at the point of exit).

When it comes to inclusion of non-technical losses, stakeholders did not have a common position. Many answered that non-technical losses should be included in the calculation of losses, although some mentioned that this should only be done for reporting purposes. With respect to evaluation of grid efficiency, the majority of stakeholders felt that non-technical losses should not be included.

Regarding the desired components that should be included in the calculation of losses, the position of stakeholders was split, especially when considering components of losses to include in transmission, compared to those to include in distribution systems, as presented in the table below.

Which of the following types of losses should be included in the calculation of overall losses and on what level? (number of responses in parentheses)				
	Transmission		Distribution	
	Yes	No	Yes	No
Technical Losses	(17)	(0)	(19)	(0)
Non-technical Losses – Hidden Losses	(5)	(7)	(7)	(9)
Non-technical Losses – non-metered consumption	(2)	(10)	(6)	(11)
Non-technical Losses – Theft	(9)	(4)	(13)	(4)
Non-technical Losses – Others[15]	(14)	(1)	(16)	(1)

Table 4: Components included in losses

Responding stakeholders were slightly in favour of a harmonised definition of power losses. Those who were in favour of introducing a harmonised definition asked for a reasonable timeframe in order to allow the necessary adaptation of their existing regulations.

[15] Such as metering errors, differences in metering, billing, and data processing.

4.2 Calculation and values of losses

4.2.1 Calculation of losses

Power losses can be determined in different ways: either by direct metering of the injected and withdrawn energy or by estimating the losses by calculation. If losses are determined by calculation, the majority of the respondents, as already stated, accomplish this by subtracting electricity withdrawals (electricity going out of the grid such as electricity for end consumers, pump storage or exports) from injections (electricity going into the grid such as electricity from producers or imports). Even though they calculate their losses through the aforementioned way, countries such as Great Britain and Greece have additional calculations for specific parts of the network. Certain parts of Belgium (under the jurisdiction of CREG and CWaPE) calculate individual losses of each electrical circuit with total losses being the sum of individual values. In Germany, any method to derive the amount of losses is allowed and this can include estimation, free valuation, and calculation.

According to the values provided in the questionnaire, the total losses in a country are not equal to the difference between their injected and withdrawn electricity in every case. This can be attributed to faults in data collection, such as not counting every network operator in a country. France, for example, submitted only data from their largest distribution system operator (DSO) which amounts to around 95% of their total losses.

On high and extra high voltage levels, most countries determine losses by measurement, since energy flows on these voltage levels are usually metered. On medium and low voltage levels, losses are mostly calculated. There are cases, however, when losses on certain voltage levels are either metered or calculated, depending on availability of meters in a specific location. Germany, Great Britain, Poland and Romania are such cases. Sometimes, the decision whether to meter or calculate depends on the type of customer on that voltage level. In Croatia, losses have to be calculated for low voltage household customers while low voltage non-household customers are metered at least on a monthly basis.

In countries such as Ireland, overall losses incurred in the transmission and distribution systems are measured, but losses at each voltage level within the distribution and transmission systems are calculated. In Spain, losses are not monitored at individual voltage levels because this is not required by the legal framework. In Finland, losses are calculated only per network operator, which means that it is impossible to know at what voltage level the losses occur. In Norway, all energy is metered except in cases such as public lighting and thus, all losses are metered. Despite knowing all electricity consumption by voltage level for the reported years, Portugal does not fully meter internal injections between medium and low voltage levels of the distribution network.

Most responding countries have obligations to have meters at all connection points. It is important to note that even in countries with such legal obligations, not every customer is required to have a meter. Cases of exemption from this requirement are emergency sirens, railway security systems, billboards, traffic management, CCTV, communication repeaters or those who pay a lump sum for electricity. In the Czech Republic, there is an additional exemption from metering for customers having a contract permitting unmetered electricity withdrawals if their power load is limited to 1 kW. Meters in service can differ according to the type of customer and not all metering processes are synchronised to occur at the same time period, even within a single country. Moreover, not all meters are the same, and differences in measuring tolerance could have an influence on power losses.

Regarding potential changes in methodology to calculate losses, no significant discussions have been reported. CWaPE and VREG of Belgium are addressing the impact of distributed generation and the lack of measurement data from prosumers. Calculations are also currently being revised in Croatia and Cyprus. In Germany, there are discussions about taking reverse flow of electricity into account when calculating losses. Lastly, in Great Britain, the DSOs convene a "losses working group", which discusses improvements in the methodology.

Regarding stakeholders' suggestions on whether losses should be measured or estimated, the majority leans towards measurement, as they consider it to be the only way to accurately determine losses. Naturally, that approach incurs certain costs: more metering points, smart meters for all consumers etc. Others believe that losses can be estimated with acceptable accuracy if network modelling is good. Most stakeholders agree that losses should be determined per voltage level, while some even suggest determining losses per network component (such as circuits or transformers).

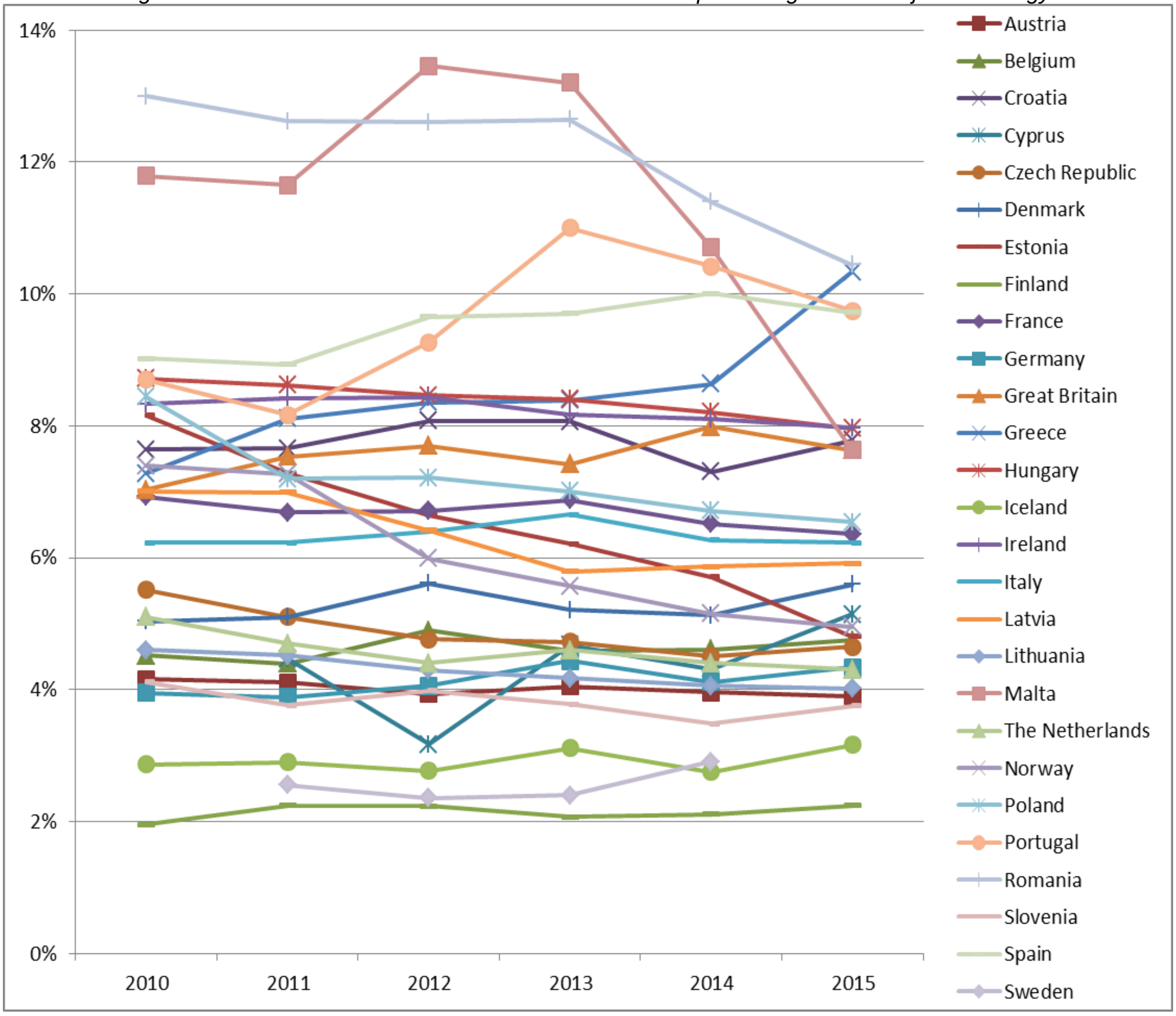
4.2.2 Values of losses

When analysing the data presented in this section, one should not forget that the way losses are dealt with can considerably differ between Member Countries. Such things as definitions of losses, how they are measured and calculated, what components they include and whether they include elements like own consumption all evidence diversity across Europe, even between neighbouring Member Countries. This means that the results should be approached with caution and not be overinterpreted and that the possibility for different approaches to losses should always be kept in mind if and when making direct comparisons between the countries.

The losses in the following figures and tables are presented as percentages of injected energy, the values of which were provided by the European regulators for the 2016 CEER questionnaire. As already mentioned, one way of presenting injected and withdrawn electricity is to have it include imports and exports, respectively. Unfortunately, information on whether all countries did this for the values in their responses is not attainable. Adding in imports to injected energy would decrease losses as percentage in this case (consequently, the same applies when adding exports to withdrawals but in this report and the figures below, losses were calculated as percentage of injected energy). It is clear, however, that imports were included in injected energy in Austria, Belgium, Croatia, the Czech Republic, Italy and Slovenia. Similarly, the lack of information on which countries included own consumption in reported losses results in an additional hindrance for straightforward comparison of losses.

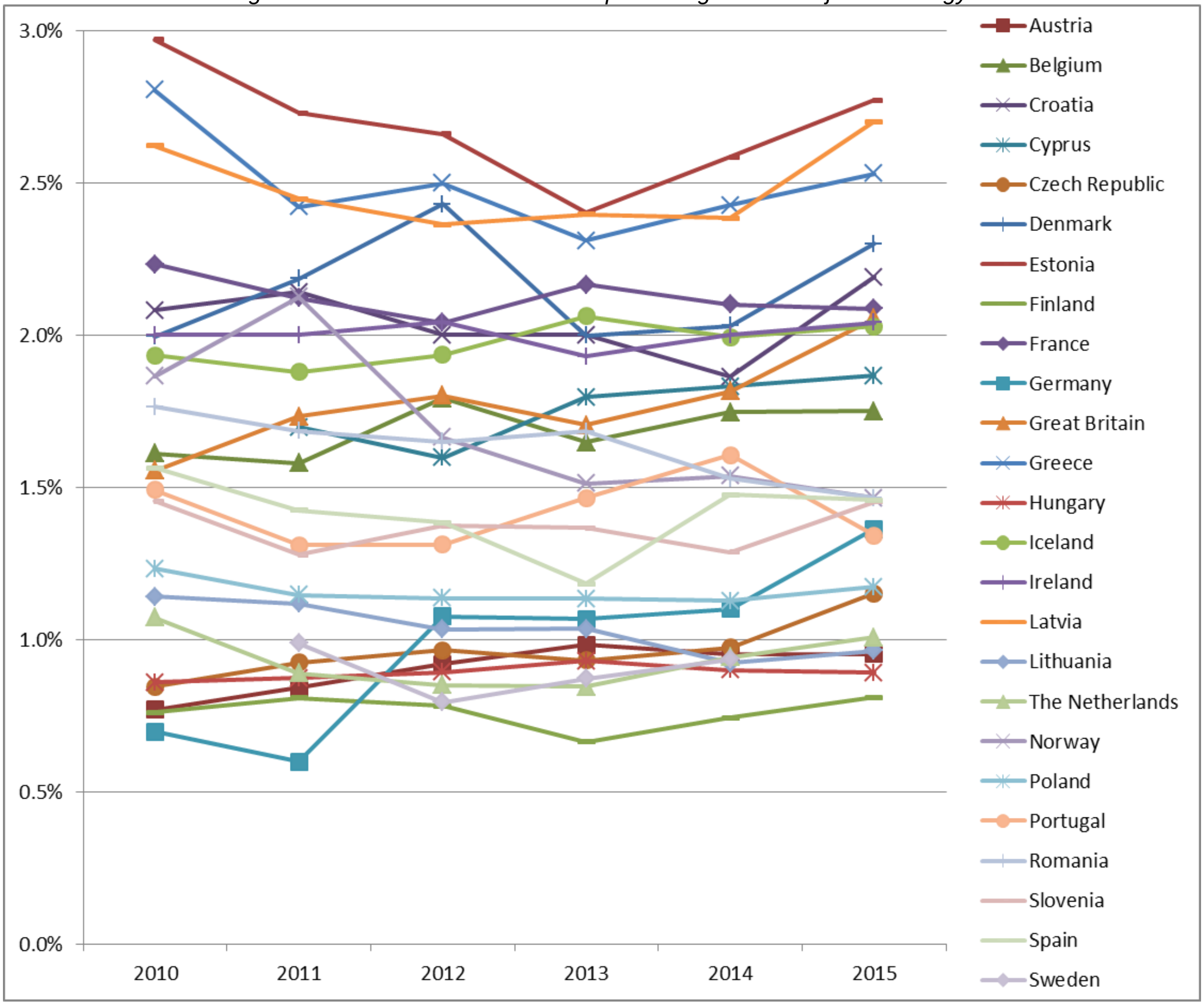
It is important to note that during the preparation of this report, losses in transmission and distribution systems were calculated as percentage of total injected energy in each Member State due to anticipated difficulties in obtaining separate values for injected or withdrawn energy at the distribution and transmission levels respectively. This approach might have resulted in different percentage values of DSO losses than those that are calculated by the system operators and then reported to National Regulatory Agencies. For this reason, it was decided not to publish separate percentage values for losses in distribution systems in the main body but in a special appendix of this report (Annex 1).

Figure 2: Total transmission and distribution losses as a percentage of total injected energy



Total losses in the electricity system can be divided into distribution and transmission system losses. As a result of higher voltage and lower current, losses are generally lower on transmission levels compared to distribution voltage levels. The reason for this is the fact that copper losses are quadratically proportional to current, as explained in Section 4.1. In other words, reducing the current by a factor of two would reduce the copper losses by a factor of four. It is important to keep in mind that while increasing the voltage (and decreasing the current) can reduce copper losses, other components, such as transformer iron losses, would rise with higher voltage. These components, however, constitute a smaller share of overall technical losses.

Figure 3: Losses in transmission as percentage of total injected energy



Overall, we note a range of between 0.4% and close to 3% power losses at transmission level as a proportion of total energy injected across the 27 countries surveyed. Transmission voltage levels typically reach 400 kV in Europe. In some cases, such as Poland and Romania, they can go as high as 750 kV which might be one of the factors for relatively low transmission system losses in these two countries (1.17 % and 1.47 % as percentage of total injections in 2015, respectively). It is important to keep in mind that transmission lines are not always operated at maximum capacity. Moreover, each country has a different definition of which voltage levels are included in their transmission grid. Countries where TSOs operate voltage levels lower than those typically associated with transmission could have higher transmission system losses as a consequence.

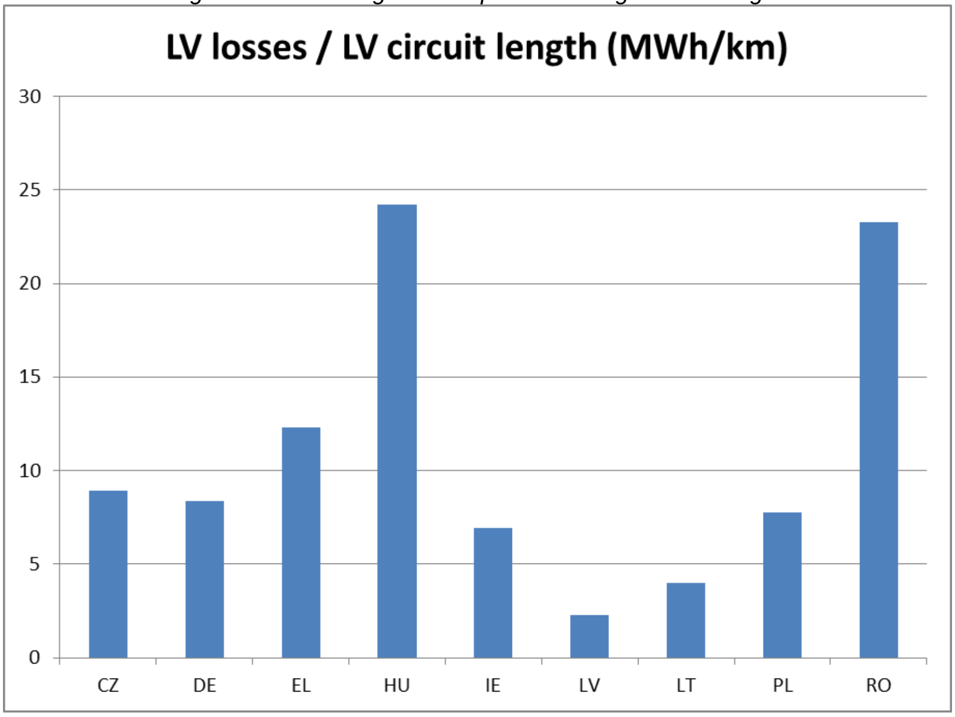
As illustrated by the figure, transmission power losses lie within a stable range, but can vary from year to year, due to a variety of factors which may be specific to each network system (see Section 4.1).

Traditionally, losses in distribution are those with the highest potential for reduction as non-technical losses play an important role in some countries since they often depend on socio-economic aspects. In general, the majority of power losses occur close to the customer, on low voltage (LV) networks followed by medium voltage (MV) grids.

An increasingly relevant issue is the effect of distributed generation on losses. Inclusion of energy related to distributed generation – such as photovoltaic (PV) panels – in reported injected energy volumes is not always guaranteed and is in some cases an estimate, even when included. This, along with the anticipated difficulties in obtaining injected energy volumes in distribution systems, was the principal reason for the decision to exclude a graphic illustration of distribution system losses from the main body of this report. Whether cases of exclusion of PV production significantly change the percentage of losses naturally depends on the overall penetration of photovoltaic energy in a country. The effect of different types of distributed generation on power losses is addressed in more detail in Section 5.1.

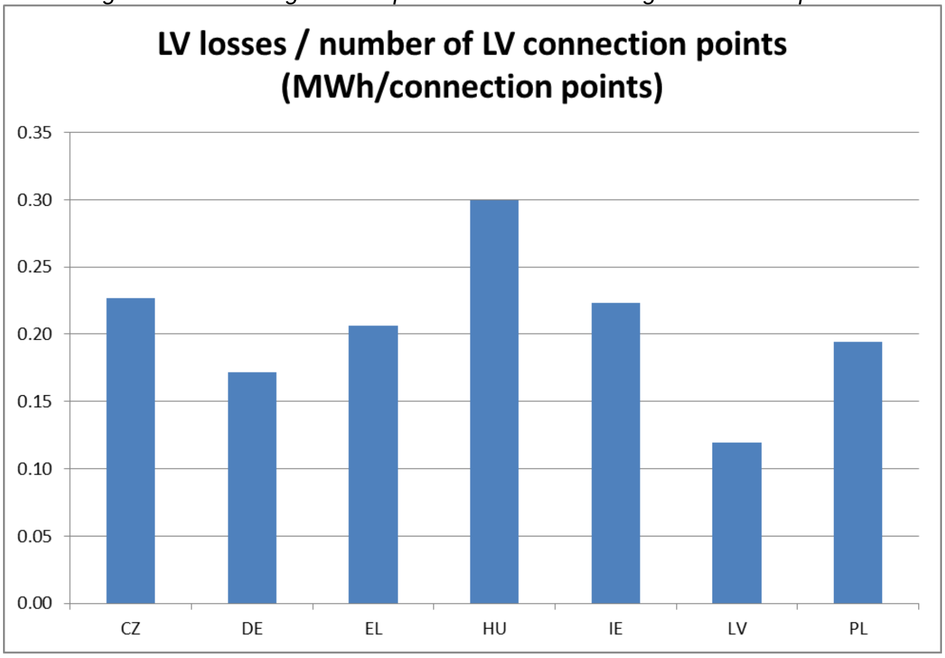
Since definitions of voltage level ranges are not standardised across Europe, direct comparison of losses per voltage level could be difficult and misleading.[16] The only voltage level with a comparable definition is low voltage (LV) which does not exceed 1 kV in any European Member State. However, for the majority of surveyed countries, disaggregated data for LV-level losses was not available. Furthermore, a direct comparison of distribution system losses would be misleading since the composition of the distribution level (LV and/or MV and/or HV) varies across the reporting countries. This led the authors to consider an alternative analysis of the occurrence of power losses at distribution level. Comparing losses in absolute terms (rather than as a percentage) would misrepresent the situation in the sense that larger countries will show larger absolute losses than smaller ones simply because their systems are larger. The result of this concern was the decision to incorporate additional parameters such as the circuit length and the number of connection points and to use them for normalisation of losses on low voltage level. Accordingly, Figure 4 and Figure 5 present LV losses per LV circuit length (regardless of whether the circuits are cables or overhead lines) and per number of LV connection points, respectively. This has only been done for the few countries that provided the necessary data. Both figures pertain to data from 2014 with a few exceptions when data for that year was unavailable for every Member State. This is the case for Germany (2013 data) in Figure 4 and Hungary (2013 data) and Ireland (2010 data) in Figure 5.

Figure 4: Low voltage losses per low voltage circuit length



[16] 6th CEER Benchmarking Report on the Quality of Electricity and Gas Supply, August 2016, page 25, https://www.ceer.eu/documents/104400/-/-/d064733a-9614-e320-a068-2086ed27be7f

Figure 5: Low voltage losses per number of low voltage connection points



4.3 Procurement of losses

Procurement of losses, defined as the procedure implemented in each country to handle the coverage of power losses, has been one of the main concerns in all European energy regulatory designs for electrical system operators.

The provisions of the European Directive 2009/72/EC[17] oblige electricity system operators to procure the energy they use to cover power losses according to transparent, non-discriminatory and market-based procedures whenever they have such a function.[18]

According to the regulatory framework established in each country under current European Directives, different approaches have been employed in the development of the solution. In most countries, network operators (TSOs and DSOs) are responsible for the procurement of losses, but in some cases, it is the duty of suppliers. Therefore, two main possibilities for procuring the energy to cover power losses are in place. In both of them, all imbalances, including those caused by losses, are treated the same way in the market, regardless of their cause.

4.3.1 Case 1: system operators are responsible for the procurement

In this case, the responsibility lies with system operators who are obligated to purchase the electricity to cover losses in the network they operate.

Energy can be procured:

- on power exchanges with day-ahead or longer contracts;
- bilaterally;
- by auctions/tenders where generators or traders submit their price offers.

[17] "Directive 2009/72EC of the European Parliament and of Council", Official Journal of the European Union, August 2009, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0072&from=EN

[18] Ibid.

It is common to use several possibilities together, for instance, a combination of organised market (long-term hedged contracts or spot market) and bilateral exchange (long-term hedged contracts). Average costs of losses are approved by the NRAs and used in the tariff calculation. In this case, losses are treated like any other induced or occurred imbalance.

This option is used in most of the CEER Member Countries, that is, Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Finland, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Romania, Slovenia and Sweden.

4.3.2 Case 2: suppliers are responsible for the procurement

In this case, electricity to cover power losses is physically bought (and, therefore, injected) by suppliers.

Each supplier buys its own energy that will be injected for compensation of losses caused by consumption of its clients in the same period. As such, estimated losses are priced at the same level as the wholesale market price to supply the consumption.

Losses are treated like any other induced or occurred imbalance. In this case, the difference between estimated losses and effective losses on the network is priced at the cost of providing the balancing energy on the balancing market. This option is used in Belgium (on the transmission grid), Great Britain, Ireland, Portugal and Spain.

4.3.3 Other cases

In addition to the two main cases, there are other possibilities for procurement of losses. For instance, a mixture of the two systems is employed in Greece where generators and importers are responsible for covering transmission losses while suppliers cover distribution losses.

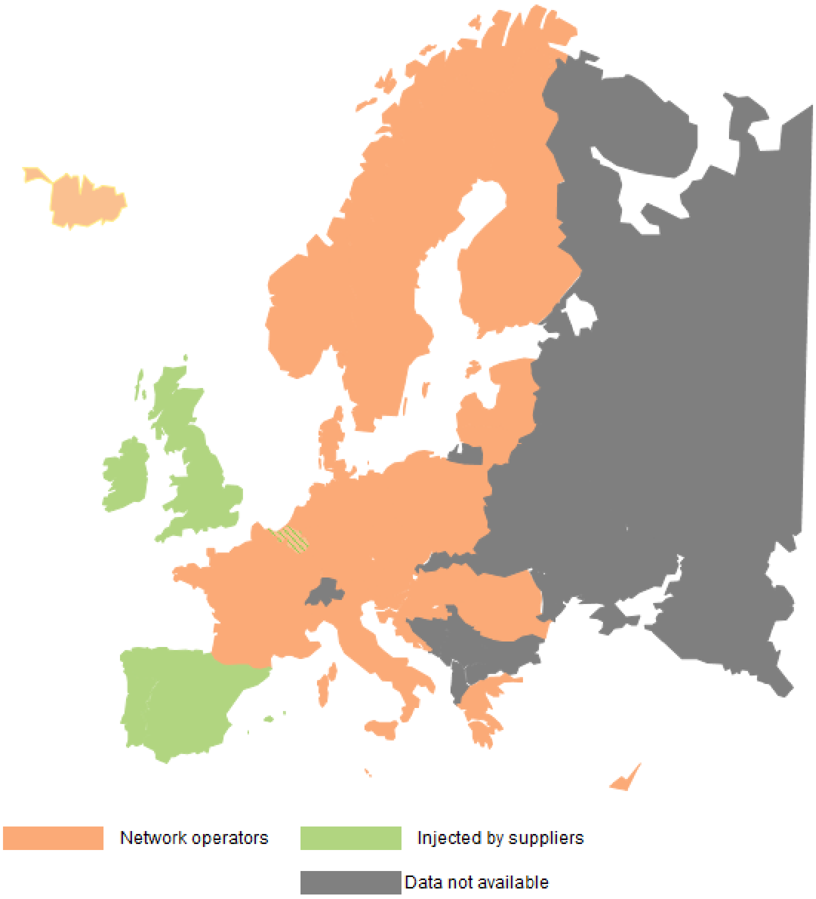
4.3.4 Actual practice

The following table and figure summarise the different solutions adopted by the referred-to countries, based on the information collected from the questionnaire. Even though this table and the questionnaire distinguish between those countries that use dedicated tariffs for losses and those that do not, it is not certain that every respondent had the same understanding of what qualifies as a dedicated tariff.

	Who	How	Tariffs
Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Netherlands, Malta, Norway, Poland, Slovenia and Sweden	Network operators (TSOs or DSOs)	PEX or bilaterally (by auctions or tenders)	Paid by network tariffs
Belgium (Regional Transm. level <70 kV, Distribution level Flanders and Wallonia), Austria, Hungary, Iceland, Latvia, Lithuania and Romania			Dedicated tariff for losses
Belgium (Federal Transm. level >70 kV), Great Britain, Greece, Ireland, Portugal and Spain	Injected by suppliers		No tariffs for losses

Table 5: Current practices for procurement and pricing[19]

Figure 6: Geographical distribution of different procurement of losses



[19] For Poland, costs related to the energy's purchase, in order to cover the losses, are included in the calculation of the variable component of the network rate in TSOs' and DSOs' tariffs.

A slight majority of responding stakeholders (10 out of 17) indicated a preference for network operators (TSOs or DSOs) being responsible for procurement of losses. Seven stakeholders would prefer suppliers to handle procurement, while one stakeholder supported both options. All answers to this question clearly pointed out that the energy to cover losses should be procured by transparent, non-discriminatory and market-based rules.

In the case of procurement by network operators, a possible solution to ensure a market-based procurement of energy to cover network losses could be the obligation for network operators to buy this energy through tenders, auctions or on organised markets. When acquisition of power losses is a responsibility of suppliers, the market players have all the incentives to purchase energy losses efficiently since they will support the respective costs.

All of the 16 stakeholders who gave feedback on the necessity of a dedicated tariff to recover the costs of losses procurement were not in favour of such a practice. Stakeholders who advocate for procurement of losses by system operators prefer that the network tariffs cover the costs of system operators including the cost of procurement. From their point of view, applying an additional dedicated tariff for losses is not necessary, with hardly any benefits for consumers.

4.4 Regulatory treatment of losses

The question of regulatory approach to losses can be addressed in several ways. Since incentive-based regulation is typically implemented for European DSOs, the regulatory choice would be to decide how to incentivise system operators to reduce (or in some cases maintain at a low level) their losses and whether such incentives are reasonable and beneficial at all. Additionally, it would be possible to introduce incentives to ensure that energy to cover losses is purchased at the best price.

The aim of incentives is to enable regulators to ensure that TSOs and DSOs implement all the economically efficient operational and investment decisions aimed at limiting/reducing the volume of power losses and the costs of the energy necessary to cover losses.

However, to be efficient, incentives should set adequate targets on a timeframe relevant for to the matter. If they are not efficient, this could lead to inefficient operational and investment decisions and to either a degradation of system operators' tariff income if the targets are set at too high a level or to undue gains if targets are set at too low a level. Therefore, incentives dealing with treatment of losses should be set correctly.

Responses to the CEER questionnaire show that incentives in almost all Member Countries apply only to DSOs. Exceptions are France and Sweden, where both TSO and DSO are incentivised on volume (in both countries) and price (France only). Some countries did not specify in their answers whether their incentive schemes apply to transmission or distribution system operator(s).

The analysis of current regulatory practices illustrates the following methods in regulatory treatment of power losses in transmission or distribution networks:

- Incentive-based regulatory models where the cost of losses is part of the general revenue cap meaning that losses are treated like any other cost component;
- Allowed rate of losses to include in tariffs capped to a maximum value in percent; and
- Mechanisms allowing the network operator to be rewarded (or penalised) if global network losses are lower (or higher) than a predetermined reference value.

In Austria, procurement costs of the energy necessary to cover losses are considered in the efficiency measurement of DSOs. In Belgium (Flanders regulator VREG only), a revenue cap is used for Totex (total expenditure), including the costs for power losses, for DSOs only. In the Czech Republic, a normative volume of losses is set by the NRA and is adjusted annually using actual annual consumption. Denmark has set revenue caps that include incentives to reduce power losses. In France, there is an incentive on both volume of losses and procurement price of electricity for covering losses and it applies to both, TSO and DSOs. In Germany, Norway and Slovenia, the costs of losses are a component of one part of the revenue cap. That part (volatile cost share) is benchmarked regularly. In Great Britain, it is intended to reintroduce a direct financial incentive on losses once smart metering data is available. The current policies are designed to incentivise DSOs to better understand and manage their losses through innovative solutions and better data management. Poland has separate schemes for DSOs and TSOs; for DSOs, losses are set by a benchmarking model; for TSOs, losses are set in tariffs using historical data and efficiency improvement factor. If that operator reaches a higher efficiency level (reduced losses), it can keep the profit. The incentive mechanism in Portugal allows the DSO to be rewarded/penalised in case of achieving global distribution losses below/above a reference value set by the NRA, on a yearly basis. The Netherlands has a yardstick regulation in place; the target is set ex-ante to a regulatory period, based on historical results and, in the case of DSOs, on the average performance as yardstick. The target is set by the NRA's calculations for the TSO.

Case Study: Power losses procurement and compensation in Portugal

In Portugal, power losses are physically injected by suppliers. Suppliers are supposed to buy their consumption needs in the most efficient way. If losses are included in these purchases, it is considered that the power losses procurement will be optimised.

Each supplier buys and, therefore, injects its own energy for compensation of losses related to the consumption of its clients in the same period, based on hourly losses profiles approved by ERSE, the Portuguese NRA.

Regarding the global system energy balance, there is no specific treatment for power losses. Power losses are treated as any other induced or occurred imbalance.

Energy procurement

Since power losses are physically injected, there are no specific tariff requirements for losses. For each programming hour, each supplier must buy and, therefore, inject its own energy, including the energy for power losses compensation related to its clients' consumption in that period.

For an LV client with an estimated energy consumption E_C for an hour h, the supplier must provide the injection of the energy E_P as follows:

$$\text{Hour (h): } E_P = E_C \times (1+\rho_{HV/RT}) \times (1+\rho_{HV}) \times (1+\rho_{MV}) \times (1+\rho_{LV})$$

where:

$\rho_{HV/RT}$ – EHV transmission network losses profile, including EHV/HV transformers.

ρ_{HV}, ρ_{MV} and ρ_{LV} – HV, MV and LV distribution network losses profiles.

For an EHV client with an estimated energy consumption E_C for an hour h:

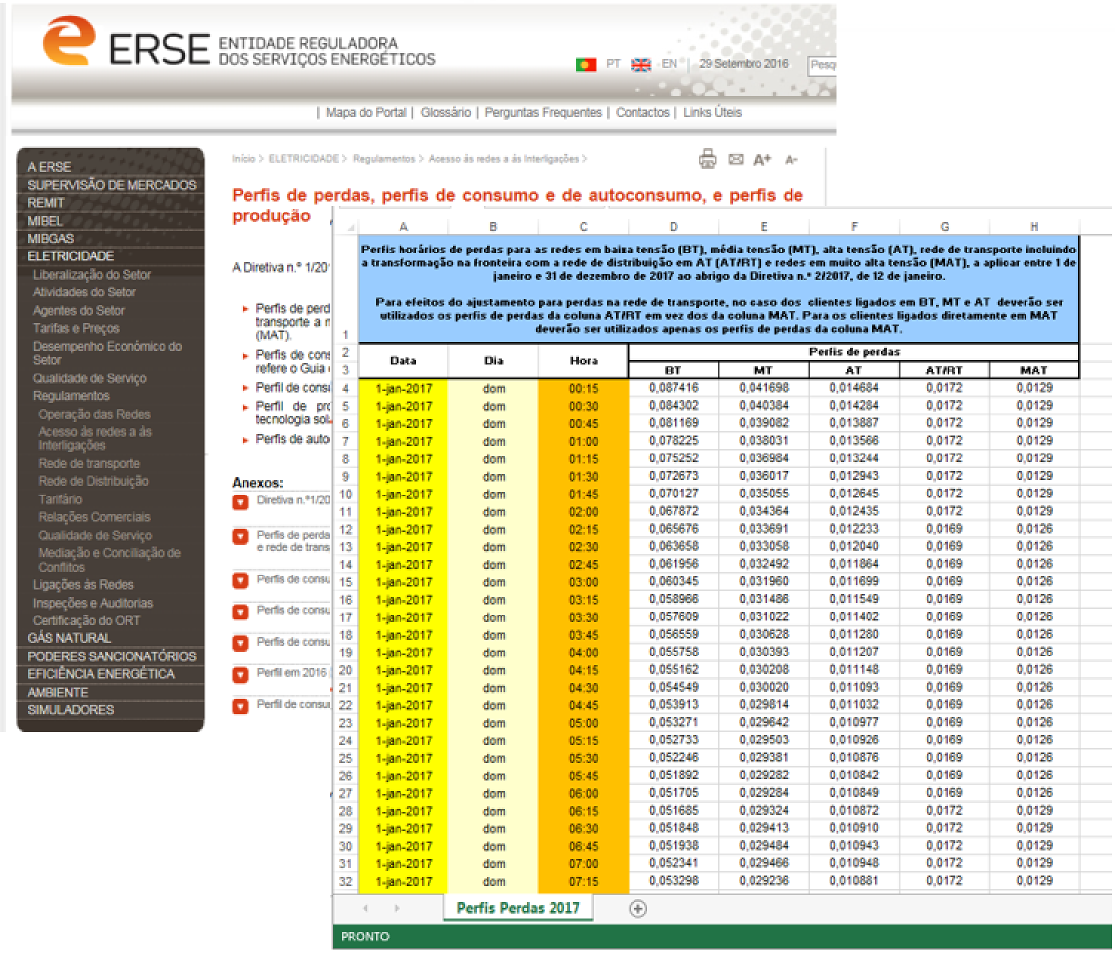
Hour (h): $E_P = E_C \times (1+\rho EHV)$

ρEHV – EHV Transmission network losses profiles, without EHV/HV transformers.

Hourly loss profiles

The values of the hourly loss profiles are differentiated by network type and voltage level, approved every year by ERSE, upon a proposal from the network operators and are publicly available for download on ERSE's website. A sample snapshot is shown in the following figure:

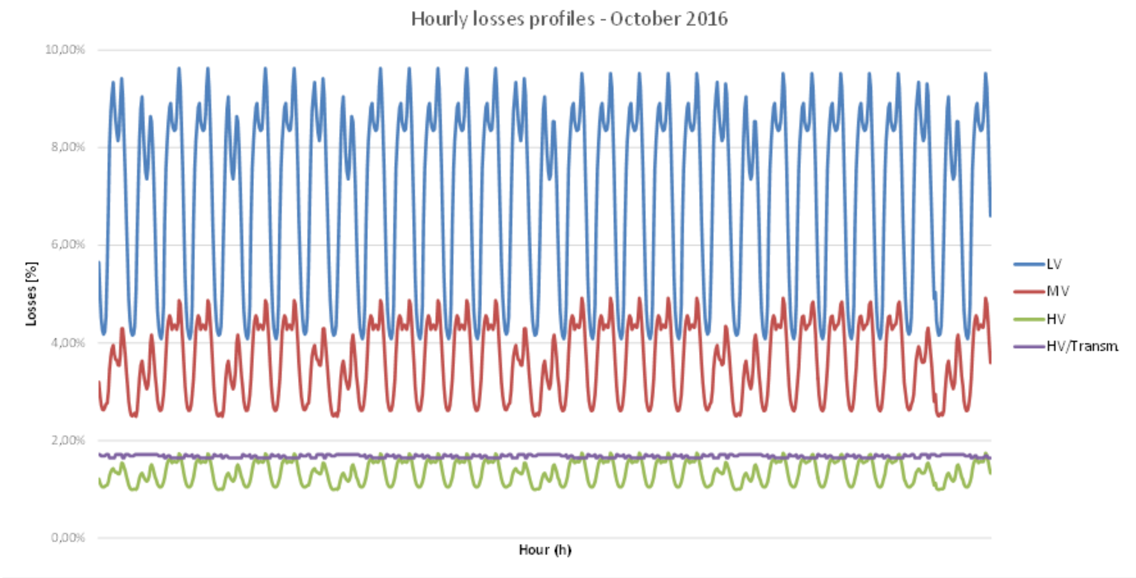
Figure 7: Snapshot of the hourly loss profiles in Portugal



Data	Dia	Hora	Perfis de perdas BT	MT	AT	AT/RT	MAT
1-jan-2017	dom	00:15	0,087416	0,041698	0,014684	0,0172	0,0129
1-jan-2017	dom	00:30	0,084302	0,040384	0,014284	0,0172	0,0129
1-jan-2017	dom	00:45	0,081169	0,039082	0,013887	0,0172	0,0129
1-jan-2017	dom	01:00	0,078225	0,038031	0,013566	0,0172	0,0129
1-jan-2017	dom	01:15	0,075252	0,036984	0,013244	0,0172	0,0129
1-jan-2017	dom	01:30	0,072673	0,036017	0,012943	0,0172	0,0129
1-jan-2017	dom	01:45	0,070127	0,035055	0,012645	0,0172	0,0129
1-jan-2017	dom	02:00	0,067872	0,034364	0,012435	0,0172	0,0129
1-jan-2017	dom	02:15	0,065676	0,033691	0,012233	0,0169	0,0126
1-jan-2017	dom	02:30	0,063658	0,033058	0,012040	0,0169	0,0126
1-jan-2017	dom	02:45	0,061956	0,032492	0,011864	0,0169	0,0126
1-jan-2017	dom	03:00	0,060345	0,031960	0,011699	0,0169	0,0126
1-jan-2017	dom	03:15	0,058966	0,031486	0,011549	0,0169	0,0126
1-jan-2017	dom	03:30	0,057609	0,031022	0,011402	0,0169	0,0126
1-jan-2017	dom	03:45	0,056559	0,030628	0,011280	0,0169	0,0126
1-jan-2017	dom	04:00	0,055758	0,030393	0,011207	0,0169	0,0126
1-jan-2017	dom	04:15	0,055162	0,030208	0,011148	0,0169	0,0126
1-jan-2017	dom	04:30	0,054549	0,030020	0,011093	0,0169	0,0126
1-jan-2017	dom	04:45	0,053913	0,029814	0,011032	0,0169	0,0126
1-jan-2017	dom	05:00	0,053271	0,029642	0,010977	0,0169	0,0126
1-jan-2017	dom	05:15	0,052733	0,029503	0,010926	0,0169	0,0126
1-jan-2017	dom	05:30	0,052246	0,029381	0,010876	0,0169	0,0126
1-jan-2017	dom	05:45	0,051892	0,029282	0,010842	0,0169	0,0126
1-jan-2017	dom	06:00	0,051705	0,029284	0,010849	0,0169	0,0126
1-jan-2017	dom	06:15	0,051685	0,029324	0,010872	0,0172	0,0129
1-jan-2017	dom	06:30	0,051848	0,029413	0,010910	0,0172	0,0129
1-jan-2017	dom	06:45	0,051938	0,029484	0,010943	0,0172	0,0129
1-jan-2017	dom	07:00	0,052341	0,029466	0,010948	0,0172	0,0129
1-jan-2017	dom	07:15	0,053298	0,029236	0,010881	0,0172	0,0129

Figure 8 below shows the difference between the hourly loss profiles by voltage level and network type.

Figure 8: Differences between hourly loss profiles by voltage level and network type in Portugal



Concerning network tariffs

Regarding the use of network tariffs, the prices of the components of each related tariff (Networks and Global Use of System) which are applied to the metered electricity, are affected by the losses adjustment factors. These factors convert the consumption quantities metered at the client referential (metering point for tariff application) to the energy injection referential (assumed to be EHV plant bus bars).

Losses adjustment factors

The losses adjustment factors, as already clarified, are differentiated by network type, voltage level and time of day (peak, partial peak, valley, and super valley). They are proposed by network operators yearly and subsequently approved and published by ERSE. The table below illustrates the loss adjustment factors for 2017, in percentage (applied to the metered values):

		Hourly period			
		Peak	Partial peak	Valley	Super valley
Transmission	γEHV	1.25	1.21	1.26	1.25
	γHV/RT	1.67	1.61	1.69	1.66
Distribution	γHV	1.62	1.46	1.21	1.01
	γMV	4.72	4.15	3.36	2.68
	γLV	9.68	8.69	7.46	4.56

Table 6: Losses adjustment factors in Portugal in 2017

Case Study: Power losses procurement and compensation in France for the French DSO Enedis

Given the importance of the cost of losses in network tariffs, CRE considers it necessary to ensure that network operators implement their best efforts to minimise it. Thus, CRE decided to introduce incentives for the control of price and volume of (French TSO) RTE and Enedis[20] losses.

For Enedis, CRE set the following mechanism in the network tariff TURPE 5 into force for the period 2017-2020:

- For each year of the TURPE 5 period, an annual reference amount of loss is determined ex post from a reference volume, proportional to the total level of injections on the distribution network and depending on coefficients related the development of smart meters and decentralized energy sources, and a strategy of reference purchases based on the actual market price recorded over the period;
- For each year, the difference between this reference amount and Enedis charges for this purchase item is covered at 80%. Accordingly, the remaining 20% constitutes a gain (or loss) for RTE in the case that actual expenses are lower (higher) than the annual reference amount. The difference between this new annual reference amount and the expenses initially planned by the tariff is fully covered.

The difference between the amount of losses covered by the tariff and the Enedis observed cost may not exceed €40 million annually (e.g. 0.3% authorised revenue).

This framework protects Enedis against variations in factors such as climate or market prices over which it has no control and takes into consideration its specificities while encouraging it to limit the increase in the purchase cost of losses.

A similar mechanism has been implemented for RTE. Yet a differentiated incentive rate for losses volumes and cost of procurement have also been introduced. Thus, the incentive rate for the volume has been reduced to 10% to take into account the potentially lower TSO flexibility in minimising losses volumes.

4.5 Summary

Various definitions of power losses are used across Europe. Incorporation or omission of certain components (especially with non-technical losses) often makes a direct benchmarking difficult, even if losses are presented as percentages of injected or withdrawn energy. Most parties that responded to a CEER questionnaire on power losses affirm that losses should be defined as the difference between the energy entering a system and the (metered and billed) energy exiting a system. A slight majority of stakeholders is in favour of harmonising the definition of power losses.

Losses can either be determined by direct metering or estimation. Metering is mostly used in transmission while estimation of losses is often (but not always) used in distribution. Percentagewise, the majority of losses occur at the low-voltage level close to consumers. Overall, transmission power losses lie within a stable range, but can vary from year to year, due to a variety of factors which may be specific to each network system. Losses in distribution have the highest potential for reduction as non-technical losses (which often depend on socio-economic aspects) constitute a significant share of distribution system losses of some countries.

[20] Enedis, a subsidiary of Électricité de France (EdF), manages 95% of France’s electricity distribution network.

Most stakeholders agree that losses should be determined per voltage level, while some even suggest determining losses per network component (such as circuits or transformers). However, direct comparison of losses per voltage level among Member Countries might be difficult, due to a diversity of operating voltages and differences in definitions of voltage levels.

Regarding procurement of energy to cover losses, the responsibility lies with system operators in most Member Countries. This is usually executed on power exchanges or bilaterally. However, in a minority of countries, the obligation lies with suppliers who buy and inject this energy. A slight majority of responding stakeholders is in favour of network operators (TSOs or DSOs) being responsible for procurement of losses. In addition, almost all stakeholders were not in favour of a requirement of a dedicated tariff for losses as they see minimal benefits for consumers in such an approach.

Member Countries that employ incentives to regulate power losses either consider the cost of losses as part of the general revenue cap (where losses are treated the same way as system operators' other costs), or allow a predetermined capped rate of losses to be included in tariffs, or allow their system operators to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value.

5 Special topics

With regard to an increased attention to energy efficiency, it is clear that a minimisation of losses can play a crucial role in reaching targets of greater efficiency.

As explained above, losses can be separated into technical and non-technical losses; hence, a reduction of losses can be achieved by reducing either of these two components.

Technical losses are affected to a large extent by the changing network architecture which has to take into account a significant increase in distributed generation, while non-technical losses might be strongly influenced by the increased usage of smart meters, among other things.

5.1 Distributed generation

In recent years, distribution networks have experienced increasing penetration levels of distributed generation (DG), mostly in the form of small-to-medium size generating units connected to medium and low voltage networks.

In general, one would expect that losses decrease when generation is located closer to demand, since the distance over which electricity is transported is shorter. Local consumption, if not connected to the transmission grid, also reduces the number of transformation steps, which results in reduced losses. However, this is not always the case, as the effect on losses is obviously influenced by the local synchronicity of generation and consumption of energy as well.

Hence, if all electricity generated by DG (for example, solar panels) were located directly at the point of consumption and if consumption occurred at the same time as generation, losses would be reduced significantly because less energy would need to be transported through the grid.

In reality, this does not happen in many cases, either due to lack of a proper operational market framework or due to the stochastic nature of generation, which is largely dependent on weather conditions. This unbalanced operation can lead to increased network flows (and thus increased losses), often translated into reverse flows from distribution to transmission systems.

In addition, larger sources of generation (such as wind parks) are not always located at a close distance to the point of consumption. Therefore, the energy must be injected into transmission grids and then transported over longer distances, which often leads to an increase in losses. Moreover, distance is not the only factor that has a major impact on network losses; circumstances of distributed generation play a crucial role as well. An issue more important than the distance is the concurrence between production and consumption patterns. For instance, if cooling is the main driver of consumption, solar production will coincide with consumption. On the other hand, if consumption is driven by heating, solar production will be less well-matched with consumption.

In summary, an increased penetration rate of DG might lead to two contrary effects regarding network losses:

- On the one hand, if decentralised energy sources are located near the point of consumption and if generation coincides with consumption, they contribute to reducing power losses;
- On the other hand, if decentralised energy sources are located far from consumption centres or if generation does not coincide with consumption, losses might increase. The main reason for this is the increased distance of power flows.

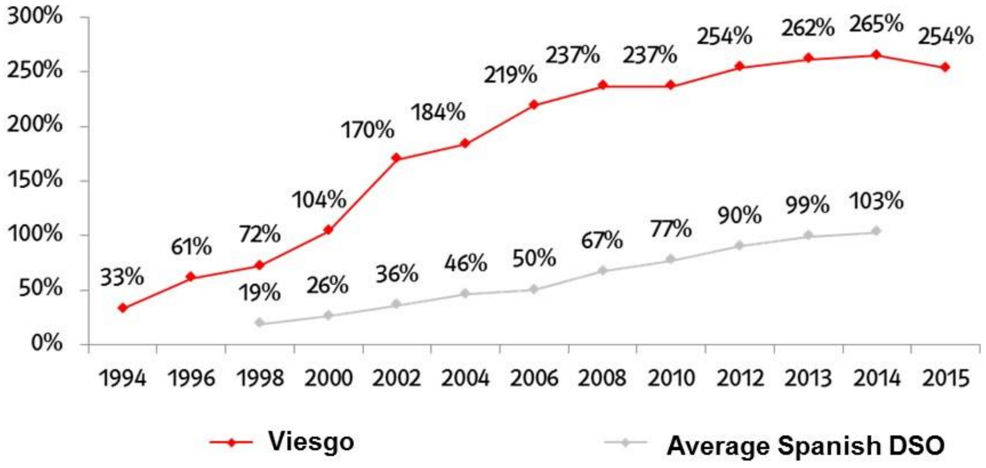
Case Study: Experiences of a Spanish DSO with effects of distributed generation on power losses

The following example is meant to illustrate the aforementioned potential circumstances related to massive distributed generation integration and losses in a medium voltage network.

Viesgo, a Spanish DSO, in cooperation with an electrical manufacturer, ABB, conducted a study in order to obtain a more in-depth understanding of the actual situation, which was experienced by this DSO due to a massive amount of distributed generation connected in its network.

The following figure shows that from 1998 to 2014, Viesgo was experiencing between 2.57 (2014) and 4.72 (2002) times the yearly average of the ratio of renewable power connected to the grid to consumption during the peak hour compared with the same ratio observed in the average for Spanish DSOs.

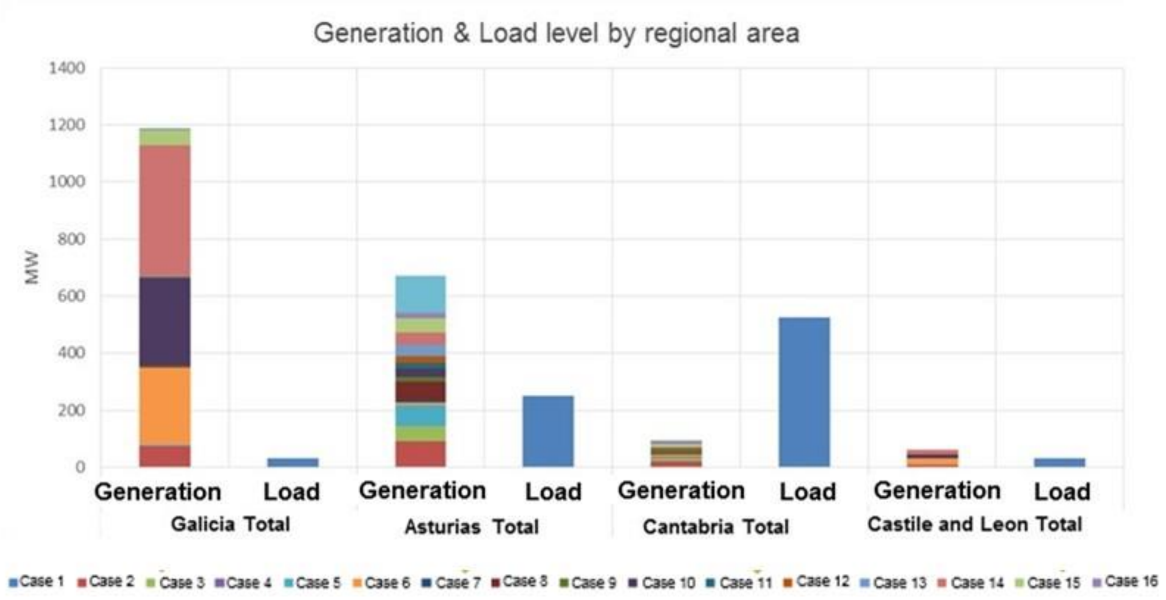
Figure 9: Renewable power connected to the grid/consumed in the peak hour (Viesgo)



In order to consider different scenarios, Viesgo's distribution network was tested with 16 different penetration rates and generation technologies. Each case was implemented in four different network areas operated by this DSO:

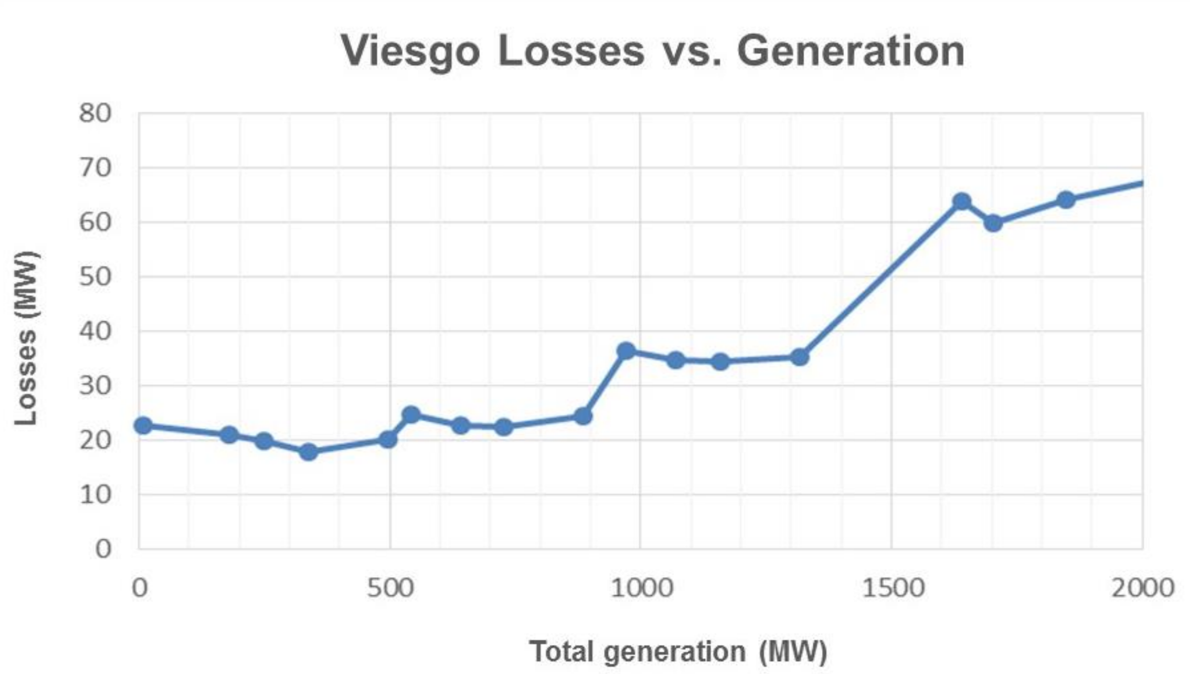
- Galicia: an area mainly characterised by a high amount of wind power and performing the function of an exporter subsystem.
- Asturias: an area that can act as an importer or exporter subsystem, depending on how much the wind blows and at what speed.
- Cantabria: an area without generation that behaves as an importer subsystem.
- Castile and León: an area that, like Asturias, can behave as an importer or exporter subsystem depending on wind power.

Figure 10: Different areas considered in Viesgo´s case study



The first result obtained by Viesgo and ABB was found by observing losses related to the amount of distributed generation in each area and each case, as seen in the figure above. It can be observed that increased renewable generation in scenarios with low penetration levels of DG has a barely-significant impact on the level of network losses. On the other hand, an increase of the renewable generation in scenarios with high levels of penetration of DG, has a quite significant and relevant impact in the level of network losses.

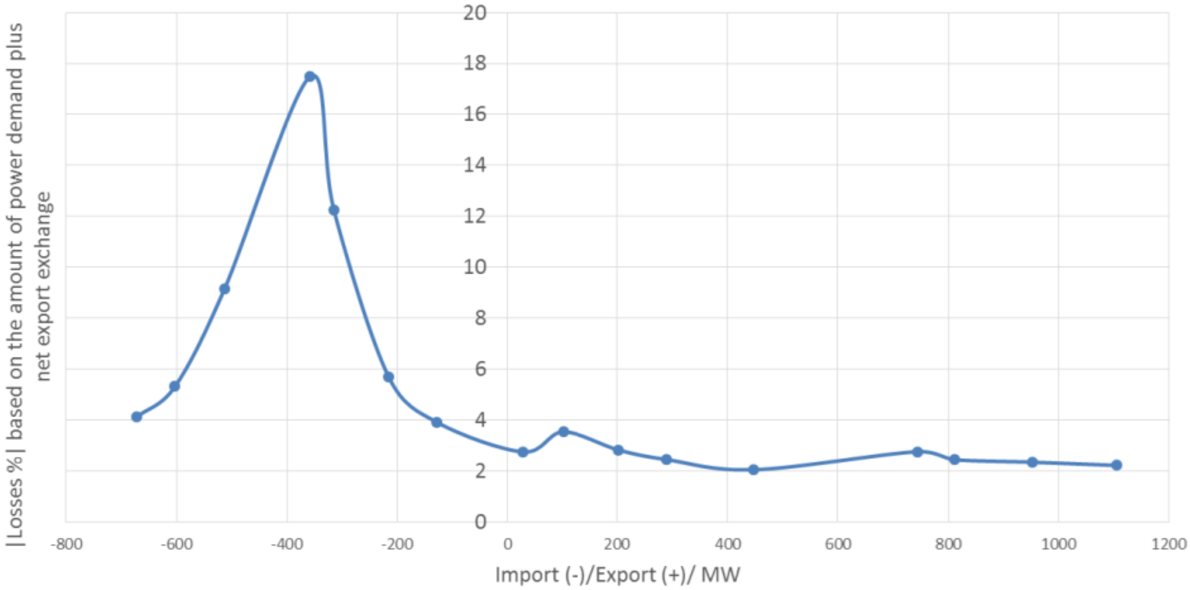
Figure 11: Absolute value of losses compared with distributed generation capacity in network



The significant and relevant impact on networks with a high penetration of DG is mainly caused by the increase in wind generation and necessity to inject wind power into transmission grid. This causes an increase of power flows to other, more distant areas, in order to meet their power demand.

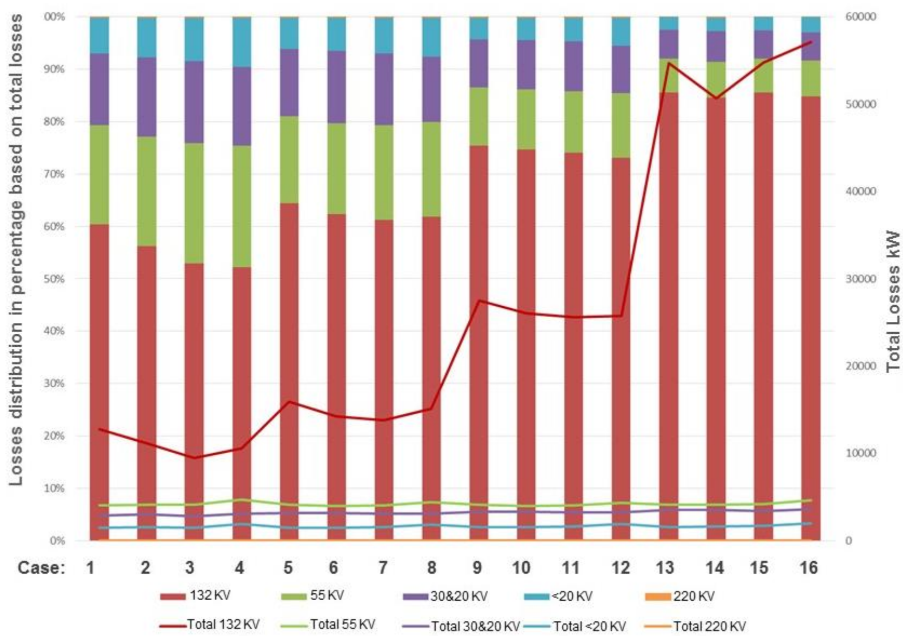
The existence of net flows of exported energy (out of Viesgo's grid) allows the level of losses to be between 2% and 4% and the absence of this condition (the existence of exported energy) causes the level of losses to be above 4% and, in extreme cases, to reach nearly reach 20%. Viesgo's formula to obtain these percentages was:
Value of losses/(demand + export-import)

Figure 12: Absolute value of losses in percentage based on power demand + net export. Comparative representation with export power demand



Considering network design and the representation of distribution losses for each case in this study, it can be clearly observed in Figure 13 that there is evidence of higher levels of losses in Viesgo's highest voltage networks (132 kV) where there is a greater presence of distributed generation. In other words, the higher the presence of wind generation, the higher the percentage of losses at 132 kV in Viesgo's grid.

Figure 13: Distribution of losses by voltage level in percentage. Representation of losses distribution for each case of study



As a result of the study, Viesgo and ABB proposed to the Spanish NRA and to the Ministry of Energy to review grid losses calculation incentives and to take into consideration the effects of renewables in losses that were not fully considered in current legislation. Their proposal is illustrated in the figure below.

Figure 14: Viesgo´s proposal for a new formula for the incentive for losses reduction

1 Current Grid Losses Methodology

Losses = ∑ Borders - ∑ Demand

% Losses = Losses / ∑ Losses

ENERGY BALANCE EXAMPLE

GWh	IN	OUT	NET
DSO-TSO	115	400	-285
DSO-DSO	400	850	-450
GENERATION	500	0	500
WIND-DSO	2,255		2,255
TOTAL BORDERS	3,270	1,250	2,020
CUSTOMERS		1,850	-1,850
		LOSSES	170

2 New Methodology Proposal (Viesgo)

Losses = ∑ Borders - ∑ Demand

% Losses = Losses / (∑ Borders + ∑ Borders (OUT)

1. CURRENT METHODOLOGY

ENERGY NET (IN-OUT)	2,020
CUSTOMERS	1,850
Losses	170
% Losses	8.42%

2. NEW PROPOSAL (Viesgo)

ENERGY IN	3,270
CUSTOMERS + ENERGY OUT	3,100
Losses	170
% Losses	5.20%

Figure 14 reflects the impact of different inflows and outflows of energy through the grid borders (defined as interconnections with the system's actors and includes customers, TSOs, DSOs and generation facilities). The result of this is a distortion of the calculation of grid losses used in DSO incentives.

When NRAs consider incentives to reduce network losses in distribution, how the grid losses percentage is calculated should be taken into account in order to avoid the effect of energy injected into the grid by distributed generation. The purpose here is to prevent a situation wherein the transmission of energy to networks of higher voltage excessively penalises distributors in areas with lower demand. Of course, this change does not perfectly resolve the issue. An individual assessment based on grid models and energy flows is the desired scenario, and would have to be applied to all DSOs in order to have a homogeneous analysis.

5.2 Smart meters

One critical issue for system operators is that non-technical losses cannot be precisely calculated. They are usually estimated as the difference between the total amount of energy fed into the distribution system and the total amount of energy recorded.

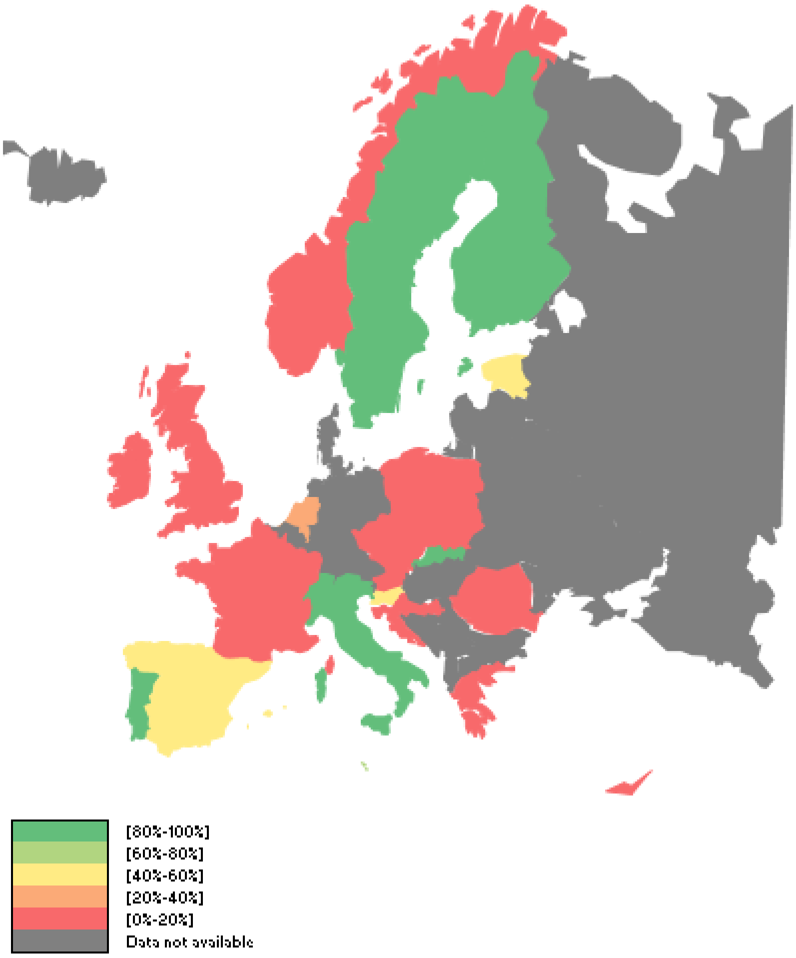
With respect to energy efficiency objectives, the proper use and measurement of electrical energy is very important. The penetration of distributed generation, the related need for restructuring of power systems and the correct measurement of energy consumption are going to be key challenges in the near future. Improvements in metering of electricity consumption are thus essential since they affect the volume of non-technical losses in at least two ways:

First, they help to reduce metering errors and identify fraud, which will lead directly to a more accurate measurement of electricity consumption. Hence, the estimation/calculation of non-technical losses will be more exact.

Second, real-time (or near real-time) reading of energy consumption and an establishment of dynamic tariffs might help to reduce the gap between peak demand and the available power at any given time, since it encourages consumers to use their appliances during off-peak hours. Hence, enabling network operators to use this combination of real-time reading of consumption and dynamic tariffs to a greater extent would necessitate improvements in current metering systems.[21]

To sum up, a higher penetration rate of smart meters has many advantages for the future. They are collect real-time consumption readings, control the volume of electricity delivered and detect non-technical losses. Therefore, the development of smart meters in Europe must be fostered in order to reduce the volume of non-technical losses. To do so, the EU aims to replace at least 80 % of conventional electricity meters with smart meters by 2020. It should be mentioned that the legal framework in support of fulfilling this aim might differ from country to country. Figure 15 illustrates the penetration rates of smart meters for household customers as of 2015.

Figure 15: Status of implementation of Smart Metering reported to CEER



[21] "Smart Metering in Electric Power Distribution System" in International Conference on Control Automation Robotics and Embedded Systems(CARE), K. Gandhi und H. O. Bansal, December 2013, https://www.researchgate.net/publication/271556180_Smart_Metering_in_electric_power_distribution_system

6 Findings and Recommendations

Reducing power losses is a difficult but an increasingly important undertaking. It not only plays an important financial role, but it also has a significant perspective in reaching energy efficiency goals.

In many cases across Europe, the costs for losses are passed on to consumers, giving system operators no incentive to reduce network losses. Proper measures should be introduced to incentivise system operators to reduce losses in their grids, or at least maintain them at low levels if they are already efficient.

This *CEER Report on Power Losses* also reveals that the definition of losses can significantly vary across Europe. Harmonising the definition of power losses would facilitate easier comparison between Member Countries. One way of accomplishing that goal could be deciding which components are included in losses that network operators report.

Technically speaking, the reduction of losses could involve increasing the voltage level; applying less transformation steps to deliver electricity to consumers; using new and more expensive equipment; or employing distributed generation (DG) in a more efficient manner. An additional option for DG would be combining it with local storage for a more efficient usage. Losses could also be reduced by optimising the flows in the network, i.e., reducing the peaks. This could be done through demand response, e.g., by providing customers with price signals to reduce their demand at peak times. Non-technical losses should be easier to minimise, especially if electricity theft is reduced and electricity consumption is recorded more accurately – both through an expanded usage of smart meters. In any case, system operators should aim to find the right balance between the costs of losses and the costs of investing in more efficient technologies.

Furthermore, it should be kept in mind that the focus for both regulation and network operators should be on managing losses effectively on the network such that they are as low as reasonably practicable, rather than necessarily requiring them to always be minimised. This is due to the need to manage a range of network parameters, where the level of losses may sometimes be traded off against other objectives.

From a financial point of view, losses are one of the key contributors to operational expenditures in power networks. Typically, optimal investment decisions involve finding the configuration of components that minimises the sum of initial investments and lifetime costs. Due to the long lifetime of the network assets, adopting a life cycle costing approach that includes losses can steer decision making when included in investment analysis. In the case of transformers, for instance, a life cycle costing approach might show that the purchase of energy-efficient equipment could be optimal decision regardless of the higher initial capital costs. Similarly, in case of power lines and given the characteristics of variable losses, such an approach might indicate increased line capacities for the reduction of technical losses. Increased capacities would then result in lower utilisation rates of the assets, in contrast to the conventional practice of using the assets as much as possible to increase capital efficiency.

Technical losses can also be affected by actions of network operators and can be classified into two main categories:[22]

- equipment replacement solutions, which focus on the use of more efficient equipment or on dimensioning the network with the target of increasing its efficiency and

[22] "Incentives to improve energy efficiency in EU Grids", Ecofys, April 2013, http://www.ecofys.com/files/files/ecofys-2013-incentives-to-improve-energy-efficiency-in-eu-grids.pdf

- network architecture or management solutions, focusing on establishing modes of operation and network structures that promote the network efficiency.

Implementing optimal and efficient energy procurement methods is an efficient way to deal with power losses. This implies that network operators should, when possible, be incentivised to make their loss procurement as economical as possible. Applying a dedicated tariff for power losses (which could incentivise customers to consume less) does not seem to offer clear benefits. Whether dedicated or not, tariffs for power losses should be transparent and cost-reflective.

One of the most important findings of this report is that the definition of losses can significantly vary across Europe. Harmonising the definition of power losses would facilitate easier comparison between Member Countries. One way of harmonising could be to decide which components are included in the losses that network operators report. Another way would be setting up a clearer differentiation between technical and non-technical losses as well as standardising whether own consumption (for network operation) should be included.

Moreover, availability of relevant data including additional disaggregated data would make an even better overview of the current situation possible. One important example is the availability of energy injected in distribution grids, which would permit calculation of distribution system losses as a percentage (of energy injected in distribution grids). This is a very important aspect of overall losses, especially since there is more opportunity to reduce losses in distribution systems.

An alternative to full harmonisation of the definition would be to agree on components of losses that should be reported so that benchmarking could be performed between those components only.

Higher data quality for losses could also help setting regulation targets more efficiently. Moreover, different regulatory approaches could be implemented for technical and non-technical losses in order to facilitate the most efficient regulatory schemes.

CEER Recommendations for reducing electricity network losses:

Overall:

1) Harmonise definitions for improved benchmarking
2) Make more data available, such as the availability of energy injected into distribution grids, which would permit the calculation of distribution system losses as a percentage of energy injected into distribution grids
3) Incentivise system operators to reduce losses instead of passing losses on to consumers
4) Employ a life cycle costing approach that includes losses when making investment decisions

Technical losses:

1) Increase voltage levels
2) Apply less transformational steps to deliver electricity to consumers
3) Utilise new and improved equipment
4) Employ distributed generation in a more efficient manner, including combining it with local storage
5) Optimise network flows – reduce peaking
6) In general, pursue network architecture and management that promote the highest efficiency

Non-Technical losses:

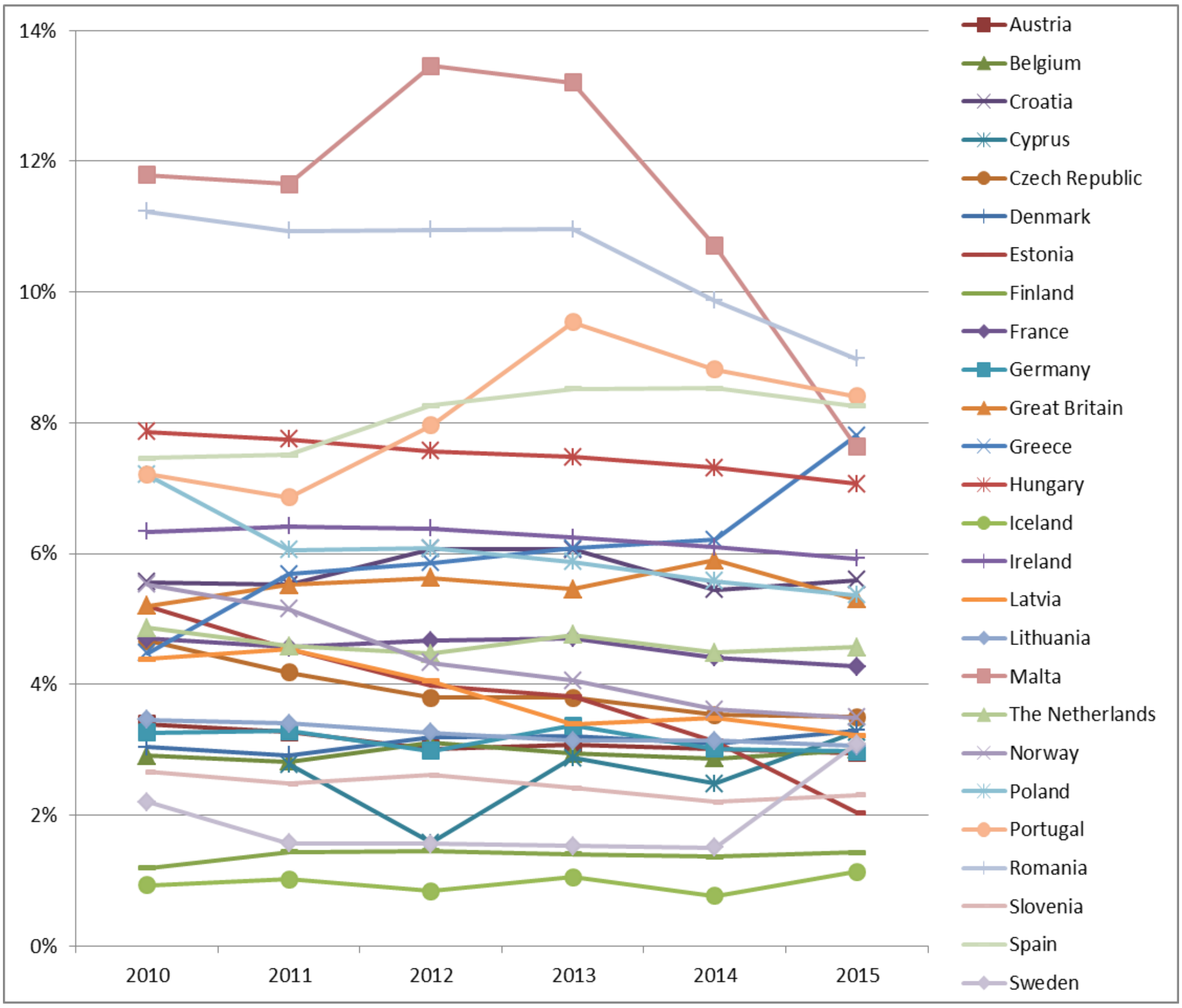
1) All countries should collect data on these types of losses
2) Focus on more accurate recording of electricity consumptions through improved metering and the use of smart meters
3) Reduce theft and other hidden losses

Annex 1 – Power Losses on distribution level

It is important to note that during the preparation of this report, losses in transmission and distribution systems were calculated as a percentage of total injected energy in each Member State due to anticipated difficulties in obtaining separate values for injected or withdrawn energy at the distribution or transmission levels. Calculating percentage values of DSO losses with this approach would give different results than those typically calculated by the system operators and reported to National Regulatory Authorities. For this reason, it was decided not to publish separate percentage values for losses in distribution systems in the main body of this report. The present report does not provide an assessment of the weight of power losses within each network system, nor does it break down losses in distribution by voltage level (low, medium, high), assuming instead a macro-view of power losses.

As shown in Figure 16, losses in distribution systems are typically higher percentage-wise than those at transmission level (see Section 4.2), ranging between 1% and 13.5%. Most countries show stable or improving levels of distribution losses over the analysed period (2010 to 2015), with a few exceptions.

Figure 16: Losses in distribution as percentage of total injected energy



Annex 2 – List of abbreviations

Term	Definition
ABB	ASEA Brown Boveri
BR	(CEER) Benchmarking Report (on Quality of Electricity Supply)
CCTV	Closed-circuit Television
CEER	Council of European Energy Regulators
CIRED	International Conference on Electricity Distribution
CRE	Commission de Régulation de l'Énergie (France)
CREG	Commission for Electricity and Gas Regulation (Belgium)
CWaPE	Commission Wallonne pour L'Énergie (Belgium)
DG	Distributed Generation
DSO	Distribution System Operator
EHV	Extra High Voltage
EQS TF	Electricity Quality of Supply Task Force
ERDF	Electricity Distribution Network France
ERGEG	European Regulators' Group for Electricity and Gas
ERSE	Entidade Reguladora dos Serviços Energéticos / Energy Services Regulatory Authority (Portuguese National Regulatory Authority)
EU	European Union
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
NA	Not Applicable
NRA	National Regulatory Authority
RTE	Réseau de transport d'électricité (France)
TOTEX	Total Expenditures
TSO	Transmission System Operator
VREG	Vlaamse Regulator van de Elektriciteits- en Gasmarkt (Belgium)

Annex 3 – List of country abbreviations

Abbreviation	Full country name
AT	Austria
BE	Belgium
HR	Croatia
CY	Cyprus
CZ	Czech Republic
DK	Denmark
EE	Estonia
FI	Finland
FR	France
DE	Germany
GB	Great Britain (GB is used for Great Britain: England, Scotland and Wales)
EL	Greece
HU	Hungary
IS	Iceland
IE	Ireland
IT	Italy
LV	Latvia
LT	Lithuania
MT	Malta
NL	The Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
ES	Spain
SE	Sweden

Annex 4 – External documents and other literature not referenced

External documents

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About CEER

The Council of European Energy Regulators (CEER) is the voice of Europe's national regulators of electricity and gas at EU and international level. CEER's members and observers (from 36 European countries) are the statutory bodies responsible for energy regulation at national level.

One of CEER's key objectives is to facilitate the creation of a single, competitive, efficient and sustainable EU internal energy market that works in the public interest. CEER actively promotes an investment-friendly and harmonised regulatory environment, and consistent application of existing EU legislation. Moreover, CEER champions consumer issues in our belief that a competitive and secure EU single energy market is not a goal in itself, but should deliver benefits for energy consumers.

CEER, based in Brussels, deals with a broad range of energy issues including retail markets and consumers; distribution networks; smart grids; flexibility; sustainability; and international cooperation. European energy regulators are committed to a holistic approach to energy regulation in Europe. Through CEER, NRAs cooperate and develop common position papers, advice and forward-thinking recommendations to improve the electricity and gas markets for the benefit of consumers and businesses.

The work of CEER is structured according to a number of working groups and task forces, composed of staff members of the national energy regulatory authorities, and supported by the CEER Secretariat. This report was prepared by the Electricity Quality of Supply Task Force of CEER's Distribution Systems Working Group.

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More information at www.ceer.eu.